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Contribution of Small Rainwater Reservoirs to Performance Off-season Vegetable Farming

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ABSTRACT

Climate Smart Agriculture (CSA) has become essential in ensuring sustainable agricultural production amidst ongoing climate change. This study aims to analyze the impact of small rainwater reservoirs (SRRs) on the performance of off-season vegetable farming in Netpala Village, East Nusa Tenggara, Indonesia. The SRRs, constructed using plastic tarpaulin with storage capacities of 3.6 m^3 and 4.3 m^3, were applied to support the cultivation of mustard greens, Chinese cabbage, cabbage, carrots, and eggplant during the December 2017 to April 2018 growing season. An on-farm research (OFR) approach was used to assess the effects of SRR implementation compared to traditional water management practices. Key performance indicators include cultivated land area, planting index, crop diversification, and farmer income. Results revealed that SRRs expanded the cultivated area by 21.07%, increased the planting index by 0.52 for mustard greens and 0.64 for cabbage, and boosted farmer income by 29.38%. Income levels were also influenced by factors such as market absorption, commodity prices, and land availability. These findings demonstrate that SRRs can enhance the resilience and productivity of smallholder vegetable farming systems by improving water availability during the rainy or off-season. SRRs offer a practical and scalable solution to address water scarcity and promote sustainable intensification in vulnerable agricultural regions.

KEYWORDS
climate smart agriculture, irrigation, planting index, water storage, water use efficiency

1. INTRODUCTION

Water scarcity remains a persistent challenge in dryland agriculture like East Nusa Tenggara Province, including vegetable cultivation, often faces limitations in productivity. This dry area needs to be supported by technical innovation, especially in the context of effective and efficient water management in existing farming businesses (Halil, 2024; Morante-Carballo et al., 2022). Efficient water use is critical for sustaining vegetable farming systems, as water availability directly influences crop growth and yield stability (Champaneri et al., 2024; Ferreira et al., 2024; Redjekiningrum and Kartiwa, 2022). While water is essential for plant development, excessive water particularly during the rainy season can lead to water logging and negatively affect yields if not properly managed (Girardi et al., 2018; Jia et al., 2016). Therefore, a good practice of water management by local farmer is required for vegetable farming, and one of the conditions for encouraging farming performance (Gleick et al., 2011; Levidow et al., 2014; Merks, 2018; Movva, 2024).

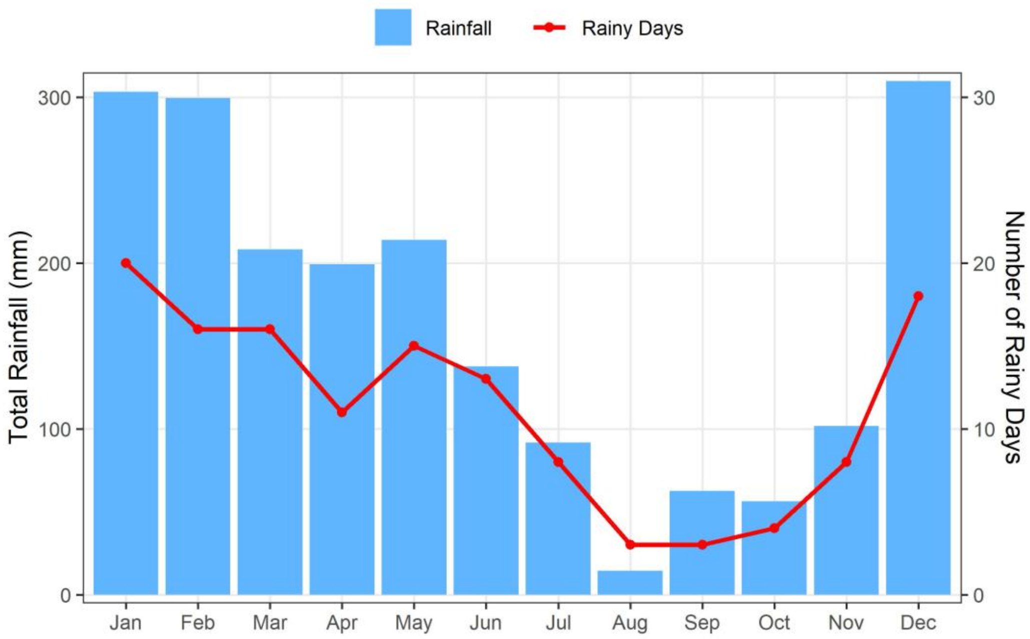

Figure 1. Average number of rainy days (red line) and Total rainfall (blue bar) for the 2009-2018 Period, North Mollo District, South Central Timor.

The farming practices of local communities in the highland villages of South Central Timor (SCT) Regency, East Nusa Tenggara (ENT), offer valuable insights into off-season vegetable cultivation. Farmers in this region cultivate a variety of vegetables as a primary source of income (Basuki et al., 2015), during the rainy season between November and April. This cultivation activity is classified as off-season farming, in which it is different from other places, where the planting and production season is carried out in the dry season (May-October) with non-rain-fed water sources. In this off-season vegetable farming, farmers have received significant economic benefits, often two to three times greater than during peak production seasons (Gyawali et al., 2022; Panta et al., 2023; Poudel, 2013; Rani et al., 2022; Sharma et al., 2023; Singh et al., 2024). The experience of farmers at SCT Regency shows that water use can be optimized beyond conventional seasonal boundaries.

The practical off-season vegetable farming faces numerous climate risks and challenges such as decreased production, limited arable area, and limited types of certain vegetables. This condition is similar with other regions engaged in similar farming practices (Degefu & Kifle, 2024; Etissa et al., 2014; Krishna et al., 2024; Panta et al., 2023; Subedi et al., 2024). To mitigate climate risk such as irregular or insufficient rainfall, local farmers in Netpala village used the SRR, which is an excavated rainwater storage tank with a size of between 3.6 – 4.3 m^3 with a tarpaulin base. The benefit of SRR is as a buffer during period of prolonged dry spells, helping to sustain crop water needs and stabilize production under increasingly variable climatic conditions.

On farm research approach, which involve farmers as cooperators has been carried out in Nepala village, SCT Regency as a village with off-season vegetable production centers. This research aims to answer the contribution of mini tarpaulin reservoirs to the performance of off-season vegetable farming. Several research questions could be raised such as how much SRR contributes to: (1) extent of cultivation area, (2) increase the planting index, and (3) increase the types of crops cultivated and increasing income.

This study evaluates the performance of vegetable farming during the rainy season, considered the off-season locally through the use of Small Rainwater Reservoirs (SRRs) made from plastic tarpaulin with capacities of 3.6 m^3 and 4.3 m^3. It focuses on six commonly grown vegetables: mustard greens, Chinese cabbage, cabbage, carrots, and eggplant. The findings aim to support year round vegetable production in off-season farming centers and strengthen Climate Smart Agriculture (CSA) strategies in regions with similar climatic constraints.

2. RESEARCH METHODS

This study employed an On-Farm Research (OFR) approach, in which researchers collaborated directly with local farmers to implement and observe technical interventions. The primary intervention involved constructing small rainwater reservoirs (SRRs), mini reservoirs lined with plastic tarpaulin and designed to collect and store rainwater for use in vegetable cultivation during the rainy season. We monitored all phenomena and variable changes at the farm in response to the application of SRR included: (1) extent of the area of arable land, (2) planting index, (3) crop diversification based on the number of vegetable species cultivated, and (4) farmer income from vegetable farming including contribution from each commodity. Six types of vegetables were mustard greens, Chinese cabbage, cabbage, carrots, and eggplant. To determine the effect of SRR adoption, changes in these variables were compared against baseline conditions from prior farming seasons that relied on conventional water management practices without SRRs. These changes have been compared with previous vegetable farming conditions, which did not use SRR.

2.1 Site and Period of Observation

This study was conducted in Netpala Village, North Mollo District, South Central Timor (SCT) Regency, East Nusa Tenggara (ENT), during the 2017/2018 planting season (December 2017–April 2018). Situated at an elevation of 900–1000 m.a.s.l., Netpala is a highland village where most off-season vegetable farmers are smallholders (Basuki et al., 2015). A total of 100 farmers participated in the On-Farm Research (OFR) involving the use of Small Rainwater Reservoirs (SRRs). Of these, 25 cooperative and consistent farmers were selected for detailed Farming Record Keeping (FRK) to document practices and collect performance data.

Climatologically, Netpala reflects typical North Mollo rainfall patterns. Based on Oldeman's classification, the area falls under climate type C3, with 5–6 wet months and 4–6 dry months, supporting one rice season and two secondary crop seasons annually (Kupang Climatology Station, 2022a). According to the Schmidt-Ferguson classification, it is a slightly wet area (type C), with annual rainfall ranging from 2,000–2,500 mm.

The rain pattern in this region follows a monsoon pattern, peaking in December and reaching a dry peak in August. Locally, the rainy season spans 20 sub-seasons from mid-November (Nov II) to late May (May III), while the dry season covers 16 sub-seasons from early June (Jun I) to early November (Nov I).

The monthly distribution of rainy days (RD) in the study area shows considerable variability. The highest average number of rainy days occurs in January, with approximately 20 RD, while the lowest occurs in August and September, with only around 3 RD. Conversely, the highest number of days without rain (DWR), or consecutive dry spells, is observed in August (28 DWR), while the lowest occurs in January (11 DWR). As shown in Figure 1, vegetable farming during the rainy season (Dec–May) still faces significant within-season drought risk, with a 33–63% chance of dry spells. This risk peaks in February, a critical period for off-season vegetables, underlining the need for water buffering through SRRs.

2.2 Treatment, Observation Variables, and Data Analysis

The main treatment in this experiment was the provision of SRR to all cooperative farmers. SRR was introduced as an innovation to support off-season farming performance in the 2017/2018 rainy season. SRR is an earthen excavation tank covered with plastic tarpaulin as a rainwater reservoir. The water reservoir functions as a buffer for plant water needs during a season with no rain days, which frequently occur in the study area.

The key variables observed in this study include: (1) the area of land cultivated for vegetable farming, (2) the planting index, (3) the number of vegetable species cultivated (species diversification), and (4) total income derived from vegetable production, including the contribution from each commodity.

Data for each of these variables were collected both before and after the implementation of Small Rainwater Reservoirs (SRRs) to assess their effect on farming performance. Comparisons were made using the same farmer groups and plots to ensure consistency and isolate the impact of SRR adoption. The five dominant types of vegetables cultivated were mustard greens (*Brassica rapa* subsp. Chinensis), Chinese cabbage (*Brassica rapa* subsp. Pekinensis), cabbage (*Brassica oleracea* L.), carrots (*Daucus carota* L), and eggplant (*Solanum melongena*). Prior to SRR implementation, rainfall was the only water source for these off-season farming activities.

2.3 Datasets and Data Analysis

Data were collected during fieldwork included: (1) cultivated arable land, (2) planting index, (3) number of vegetable species (diversification), and (4) farmer income, including contributions from individual crops. These variables were measured before and after the implementation of Small Rainwater Reservoirs (SRRs) to assess their impact. The data were analyzed using IBM SPSS 26 in three stages:

1. Mean Difference Analysis: A paired sample t-test was conducted to evaluate changes in income, cultivated land area, planting index, and the number of vegetable types before and after the implementation of Small Rainwater Reservoirs (SRRs).
2. Correlation analysis was performed to examine the relationships between selected economic and physical variables. For the economic variables, the analysis focused on the relationships between SRR volume and income, planting index and income, as well as the

Figure 2. Implementation of Small Rainwater Reservoirs in the field by Netpala farmers in off-season vegetable farming (Credit: Tony Basuki)

number of vegetable types cultivated and income. Meanwhile, for the physical variables, the relationships assessed included SRR volume with planting index, SRR volume with the number of vegetable types, and SRR volume with the area of cultivated land.

3. Simple Linear Regression is sed to assess the predictive relationships among selected variables (Greene, 1993).

3. RESULTS

3.1 Techniques for Off-Season Vegetable Cultivation

The dominant vegetable crops grown by farmers in the study area included mustard greens (*Brassica rapa* subsp. chinensis), Chinese cabbage (*Brassica rapa* subsp. pekinensis), cabbage (*Brassica oleracea* L.), carrots *(Daucus carota* L.), and eggplant (*Solanum melongena*) (Basuki et al., 2015). Mustard greens, Chinese cabbage, and cabbage were the most preferred crops, with over 50% of farmers selecting them as their main commodities. In contrast, carrots, and eggplant had lower preference levels, with less than 40% of farmers choosing them.

In terms of planting frequency, mustard greens had the highest planting index per season among the five crops, followed by Chinese cabbage. This high planting index for mustard greens was attributed to their short growth cycle (30–35 days) and strong market demand. A planting index of 2.72 for mustard greens indicates that, on average, farmers could harvest the crop nearly three times within one growing season. In comparison, the other four crops had a planting index of less than one, and some farmers did not cultivate carrots or eggplant at all during the study period.

As previously mentioned, vegetable farming in the study village is classified as off-season farming, conducted from December to April during the local rainy season. This contrasts with typical practices in East Nusa Tenggara (ENT), where vegetable cultivation generally takes place in the dry season using alternative water sources. In off-season farming, water relies primarily on rainfall, making its performance highly dependent on seasonal rainfall conditions.

The way to irrigate or utilize rainfall for planting vegetables is very simple, namely directly irrigated naturally or there are some farmers who try to accommodate it in dug holes or storage drums from house gutters. Other cultivation measures, such as knowledge of seed selection, seeding, planting methods, fertilization, pest and disease control and post-harvest handling of each commodity cultivated, are relatively good. These practices likely supported by farmers accumulated experience, access to information, and the presence of an effective local market system, all of which contributed to the overall performance of the vegetable farming sector.

3.2 Summary of Observational Data

Field observations showed that Small Rainwater Reservoirs (SRRs) were typically placed in the middle of vegetable plots, allowing for direct collection of rainwater (Figure 2). Under normal rainfall conditions, SRRs were able to reach full capacity in less than two weeks, demonstrating their effectiveness in harvesting and storing rainwater for supplemental irrigation.

A statistical description of the effects of SRR (after) compared to before using SRR at the respondent level

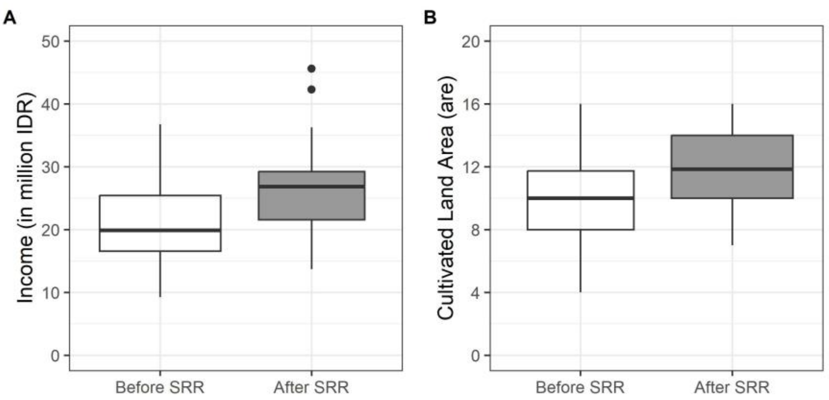

Figure 3. Boxplot changes in (A) income (in million) and (B) cultivated area (are), yellow color represent condition before SRR, green color represent condition after using SRR, and black dot.

is summarized in Table A2. Table A1 highlights the average changes observed among the 25 respondent farmers who adopted SRRs. These changes include increases in cultivated land area (measured in are), the number of vegetable types grown, and the planting frequency (planting index). The comparison of conditions before and after SRR implementation indicates a significant improvement in farming performance. The changes were reflected in the increase in gross income received by farmers, which was depicted in the economic analysis sub-chapter in this paper.

3.3 SRR Contribution to Cultivated Area, Planting Index, and Crop Diversification

The implementation of Small Rainwater Reservoirs (SRRs) contributed significantly to changes in three key variables: cultivated land area, planting index, and the number of vegetable types grown. These changes were statistically analyzed using a paired sample t-test, comparing the conditions before and after SRR implementation (Figure 4, Table A2). Referring to Figure 3B, the average cultivated area increased from 9.68 *are* to 11.72 *are* after SRR adoption. Figure 4 further illustrates that all five vegetable commodities experienced an increase in planting frequency, including those that were previously not cultivated. This suggests that the presence of SRRs encouraged crop diversification.

In terms of planting index, variable for all commodities showed positive changes, where cabbage and green mustard farming experienced the highest index increase, namely 0.64 and 0.52 respectively. This means that farmers who only plant 1 time/season have increased to 1.6 times/season for cabbage crops, and farmers previously only planted 2.72 times each season, can increase to 3.24 times/season. Meanwhile for the other three commodities, although there was a change in the planting index, the changes were less pronounced.

Regarding the increase in cultivated land after the implementation of SRRs, the analysis showed a highly significant difference ($\alpha < 0.01$) between the area planted with vegetables before and after SRR introduction. This indicates that SRRs played a key role in enabling farmers to expand cultivation. Three main factors likely contributed to this outcome: (a) the availability of a reliable water source gave farmers the confidence to increase their operations, (b) consistent moisture from SRRs addressed the high sensitivity of vegetables to drought stress, and (c) the expectation of higher yields and income encouraged greater land use. The observed changes in land area, planting index, and crop diversity suggest that SRRs not only supported land expansion but also encouraged production intensification, particularly for cabbage and mustard greens. This shift is likely due to the SRRs' role in stabilizing soil moisture during rainless days. Farmers' choice to increase the planting index for these crops was likely influenced by strong market demand and favorable prices. Expansion at the on-farm level was also closely related to farmers' experience and their ability to respond to market conditions.

3.4 SRR Contribution to Cultivated Area, Planting Index, and Crop Diversification

3.4.1 SSR Volume with Planting Index

There were two measures of SRR volume in this study. Previously it was thought that the volume of water stored in the SRR would affect the cropping index. The more water the SRR can hold, the higher the planting index will be. The results of statistical analysis (Table A2) show that there is no relationship between the volume of water that can be stored in the SRR and

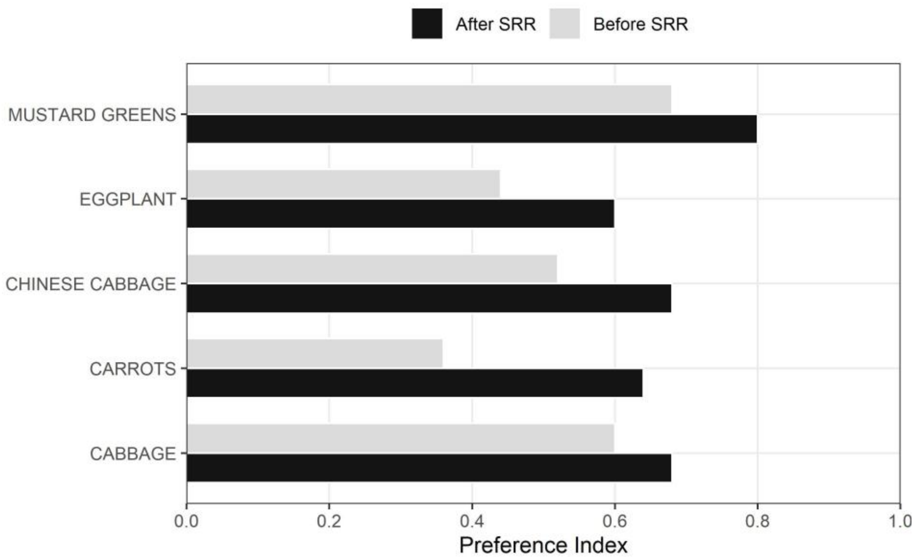

Figure 4. Preference index for any type of vegetable, where grey bar shows before and black bar shows after SRR Application

the cropping index which is not statistically significant (α > 0.1).

Several factors likely contributed to this result: (a) rainfall was evenly distributed throughout the season, reducing the need for irrigation from SRRs; (b) rainfall during the planting period was limited, offering little impact on planting index; and (c) some farmers were engaged in other work, which may have limited planting activities. These factors align with previously discussed rainfall characteristics. Overall, the presence of SRRs contributed to an increased planting index, but the volume of stored water itself did not significantly affect it.

3.4.2 SRR Volume and Number of Commodities

In both cases, there is a positive relationship between the volume of rainwater collected in the SRR and the choice of how many vegetable commodities to plant. The data showed a positive trend: farmers with an average SRR volume of 3.9 m^3 typically cultivated 3–4 different vegetable types. However, this relationship was not statistically significant (α > 0.1). This finding suggests that crop selection was more strongly influenced by external factors such as ease of cultivation, market saturation, price considerations, and consumer preferences. Many farmers reported selecting crop types based on existing customer demand, rather than solely on water availability.

3.4.3 SRR Volume and Cultivated Land Area

It was hypothesized that larger SRR volumes would encourage the expansion of cultivated land, as water availability is a critical consideration for vegetable farming. Although farmers did expand their cultivated area post-SRR implementation (to an average of 11.72 are), the relationship between SRR volume and cultivated land area was not statistically significant (α > 0.1). This maybe due to (a) rainfall distributed evenly throughout the vegetable growing season, (b) limited arable land so that it cannot increase the area, and (c) limited business capital and labor. Environmental resource support, including arable land, is an important support in introducing and expanding innovation (Treakle, 2014).

3.5 SRR Contribution to Cultivated Area, Planting Index, and Crop Diversification

The performance of vegetable farming is closely related to the market (Constantin et al., 2022). Especially for off-season vegetable farming in this study, it has survived for quite a long time and obtained market incentives in the form of stable prices and demand for a long period of time, because this area is able to supply its production, when production centers in other places (on-season) cannot provide services (Basuki et al., 2015). This consistent market presence is supported not only by strategic timing but also by stable soil moisture conditions during the rainy season, conditions known to enhance vegetable yields. The presence of SRR innovation has proven that the performance of vegetable farming can still be improved, where one of these phenomena is an increase in gross income received by farmers. The following is an analysis that links the contribution of SRR implementation to several economic variables (income), as well as the relationship between the variables of planting area, planting index, the number of types of crops planted and the income received by farmers.

3.5.1 Economic Contribution of SRR Implementation

Before the introduction of SRRs, farmer income ranged from IDR 9.2 million to IDR 36.7 million per season, with an average of IDR 20.6 million. The difference in income before and after using SRR is IDR 6 million per season or an increase of 29.3 percent. The results of statistical tests (t-test) show that there is a significant difference ($\alpha < 0.01$) between household income before and after using SRR. The income of each farmer before and after using SRR is presented in Figure 3A.

Agricultural resources in Netpala Village are a mainstay in driving the lives of the village community. Cultivation of various vegetable crops is a source of cash income for households. Food crops grown on dry land as a source of family food. Apart from that, there are household scale livestock businesses, namely raising pigs, cows, and chickens. Pigs and cattle are a source of cash income which is investment capital for the family. Farming households optimize all the resources they have to achieve better welfare (Basuki et al., 2023).

By improving water storage facilities, the productivity of vegetable farming makes a significant contribution to the formation of family income. This will be a driving force for higher income from vegetables by implementing good agricultural cultivation practices (Good Agricultural Practices) starting from preparation, implementation, to harvest and marketing.

3.5.2 Relationship Between SRR Volume and Income

It was suspected that there is a positive relationship between SRR volume and the income received by farmers. The greater the volume of rainwater that can be collected through SRR, the greater the opportunity to expand business land or planting frequency. However, statistical testing showed that in the case of Netpala Village, the volume of SRR did not significantly influence income ($\alpha > 0.1$). This happened because influenced by several things; namely (a) price, a good price when farmers sell vegetables will positively influence their income, (b) frequency and intensity of rain. The frequency and even intensity of rain will affect the growth and development of vegetable plants, where water use from SRR is not much. (c) Frequency of planting and harvesting vegetables when rainfall is even. The greater the frequency of planting and harvesting will affect income, so the SRR volume does not directly affect income.

From these results, the lessons that can be learned in vegetable farming were (a) preparing the land well, on time when the rain starts to fall will be very helpful in the vegetable production process, so that the frequency of planting and harvesting will be higher, and (b) information on prices and types vegetables that the market needs was very important to avoid oversupply which will suppress selling prices.

A study on vegetable cultivation in Karnataka in India, which is classified as an area with limited water resources, shows that vegetable farming, especially cabbage and cauliflower farming, is superior in terms of profit or income by farmers compared to cereal crops. Note this that farmers must be able to have capacity in water use efficiency applications. The implications of this practice are part of climate smart agriculture and are related to the promotion and strategy of maintaining vegetables that can increase agricultural income (Arpitha et al., 2024). In addition, if farmers can master efficient water use technologies, it will allow for the sustainability of farming, such as the experience of agricultural sustainability in rural Southern Brazil (Perlin et al., 2019).

3.5.3 Relationship Between Planting Index and Income

The planting index showed a positive and statistically significant relationship with income ($\alpha < 0.08$). This result confirms that higher planting frequencies made possible in part by SRR support directly contribute to greater household income. Encouraging the adoption of SRRs is therefore recommended as a strategy to enhance planting intensity. Multiple planting and harvesting cycles within a single season provide farmers with more market opportunities and increased revenue potential.

3.5.3 Relationship Between Crop Diversification and Income

Crop diversification defined as the number of vegetable types cultivated per season can potentially influence income (Sehgal, 2023). However, the statistical analysis in this study found no significant relationship between crop diversification and income ($\alpha > 0.1$). But on the other hand, the data also shows that of these five types of vegetables planted, the types of vegetables grown with the implementation of SRR tend to be almost the same as the types of crops before SRR, unless there is an increase in planting area. This means that, it is likely that farmers in Netpala village, still tend to stick to the previous type of crop to avoid risk. Another thing is that they are part of a market system that holds fast to guaranteeing supply with pre-built market partners. Therefore, the contribution of SRR to farmers' income tends to come from increasing the planting area and increasing the planting index.

In contrast to findings from Uzbekistan, crop diversification is recommended as a key strategy to ensure food security through diverse planting systems. Farmers who diversify crops tend to have much higher incomes compared to those who remain mono cropping (Rustamova et al., 2023). Similar research in Northern Ghana, found that crop diversification significantly improves efficiency and reduces income variability. It is even recommended that crop diversification could be an ideal Climate Smart Agriculture (CSA) strategy to promote agricultural growth and resilience (Mzyece & Ng'ombe, 2021). This condition is different because the context of this diversification is different from the case of farming in this research village, where the context is broader which includes food commodities.

4. DISCUSSION

Efficient water management and utilization in agricultural production is essential, especially in arid and semi-arid regions such as East Nusa Tenggara (ENT) (Biswas et al., 2025; Soujanya & Gurjar, 2024). Farmers in Netpala Village have long practiced the direct use of rainwater to irrigate off-season vegetable crops. With years of experience, they have capitalized on this opportunity to meet local market needs, including supplying vegetables to the Kupang City market. This reflects the resourcefulness and local knowledge of farmers in cultivating vegetables outside the main growing season.

The SRR technology, which is the focus of this study, has demonstrated a significant contribution improving farmers' income by 21% compared to previous farming without SRRs. This gain results from increases in the planting index, expansion of cultivated land, and greater crop diversity, as presented earlier in this paper. These positive changes in all three physical variables and one economic variable are an expression of the previous expectation that SRR will be able to improve the performance of vegetable cultivation in the off-season.

However, responses from farmers indicate that the impact of these improvements may be approaching a saturation point. This is supported by the analysis results, which show that the volume of SRR does not significantly correlate with physical variables or income. While SRR has triggered positive changes, the overall performance of off-season vegetable farming is likely influenced by additional factors not fully captured in this study.

It is suspected that other influential factors include market demand, price dynamics, labor availability, land constraints, and farmers' risk tolerance (Clinton & Ie, 2023; Ummah et al., 2021; Wu et al., 2022). Nonetheless, SRRs were positively received by farmers, who acknowledged them as an effective water buffer during dry spells. This is in line with the main benefits of SRR and the needs of small farmers. In the experience of this research, it was observed that the rainwater storage in the SRR used did not drain all the water in the SRR. This can be understood because the number of days without rain was generally no more than 5 days during the research. The lack of soil moisture during this period of days without rain can be compensated for by the availability of water in the SRR.

To determine the resilience of SRR to become an innovation to support vegetable farming, it still needs to be tested more widely. It is recommended that this technology be tested further both in areas like Netpala and in new locations without prior off-season vegetable farming experience. Expanding this research would also help evaluate SRR's potential as a Climate Smart Agriculture (CSA) innovation. Beyond economic benefits, SRRs could also support household-level health and nutrition by ensuring more consistent access to vegetables providing calories and dietary protein.

Policy support is crucial to promote the widespread adoption of SRRs (Molénat et al., 2023; Owusu et al., 2022; Soekarno & Harahap, 2024). However, several obstacles were encountered during the introduction of SRR. Initial responses from farmers varied. The primary constraint was limited labor to dig the SRR pits. As a solution, some farmers collaborated in mutual aid groups, while others hired external labor to complete the task. Furthermore, after construction, initial enthusiasm was low due to the delay in water collection. Farmer interest began to grow once the SRRs were filled and dry days started occurring at which point the benefits became tangible.

Thus, the results of this research can be a reference in formulating CSA for small farmers (smallholder farmers) both in off-season vegetable production center areas in utilizing efficient rainfall, and could be developed in on-season vegetable production center areas. season so that this region can produce all year round, without seasons. With proper support and adoption, these technologies could help ensure year round vegetable production, reducing dependence on seasonal rainfall patterns.

5. CONCLUSION

The contribution of SRR (Small Rainwater Reservoir) to off-season vegetable cultivation is evident in several key aspects. First, SRR encouraged an increase in cultivated area by 21.07%, from 9.68 are to 11.72 are per farmer household per season. Second, it increased the frequency (planting index) of planting, specifically for mustard greens (*Brassica rapa* subsp. chinensis) by 0.52, cabbage (*Brassica oleracea* L.) by 0.64, Chinese cabbage (*Brassica rapa* subsp. pekinensis) by 0.16, and carrots (*Daucus carota* L.) by 0.20. Eggplant (*Solanum melongena*) did not show an increase. These improvements led to a gross income increase of 29.38%, from Rp. 20,564,080 per season to Rp. 26,607,640 per season.

However, the contribution of SRR to the performance of off-season vegetable cultivation is experiencing saturation or reaching its maximum. This is supported by the results of correlation analysis, which show no significant relationship between SRR volume and variables such as income, cultivated area, planting index, and the number of vegetable types cultivated. It is strongly suspected that the effectiveness of water management through SRR is also influenced by other factors such as market demand, price, land availability, labor, and capital.

Nevertheless, SRR innovation has proven to function effectively as a buffer against water shortages or as supplementary irrigation during rainless days when soil moisture levels decline. In addition to increasing income, the introduction of SRR has expanded employment and business opportunities throughout the production process from cultivation to harvesting and marketing. It creates job opportunities for household members to make productive use of their time, and opens business opportunities for farmer groups involved in marketing, processing, and preparing vegetable based food products.

The results of this research can serve as a reference in formulating Climate Smart Agriculture strategies for smallholder farmers, both in off-season vegetable production centers that utilize efficient rainfall, and in on-season production areas so that these regions can achieve year round vegetable production, regardless of seasonal limitations. Moreover, beyond market sales, the harvested vegetables can also be used to fulfill the nutritional needs of families, especially children, toddlers, and pregnant or breastfeeding mothers. This contributes to efforts to reduce stunting in rural areas by providing education and training for vegetable producing households.

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ANNEX

Table A1. Average variables before and after SRR implementation.

Change/Respondents	Average
Area (*are*) (Before)	9.68
Area (*are*) (After)	11.72
Who planted mustard greens (Before)	0.68
Who planted mustard greens (After)	0.8
Who planted Chinese cabbage (Before)	0.52
Who planted Chinese cabbage (After)	0.68
Who planted cabbage (Before)	0.6
Who planted cabbage (After)	0.68
Who planted carrots (Before)	0.36
Who planted carrots (Sesudah)	0.64
Who planted eggplant (After)	0.44
Who planted eggplant (After)	0.6
Planting index mustard (Before)	2.72
Planting index mustard (After)	3.24
Planting index Chinese cabbage (Before)	1.28
Planting index Chinese cabbage (After)	1.44
Planting index cabbage (Before)	0.96
Planting index cabbage (After)	1.6
Planting index carrots (Before)	0.6
Planting index carrots (After)	0.8
Planting index eggplant (Before)	0.44
Planting index eggplant (After)	0.48

Table A2. Summary of statistic analysis.

Variable	T value	Significance (2-tail)
Area of cultivated land before and after SRR	16.790	0.000
	22.764	0.00
Income before and after SRR	15.315	0.000
	17.535	0.00
Variable	**Pearson Correlation**	**Significance (2-tail)**
Relationship between Number of Types of Vegetables and Income	0.829	0.0829
Relationship between SRR Volume and Planting Index	-0.083	0.695
Relationship between SRR Volume and Number of Commodities	-0.018	0.930
Relationship between SRR Volume and Cultivated Land Area	-0.096	0.647
Relationship between Plantation Index and Income	-0.357	0.080